Multi-depth Blind Vias in Surface Mount Pads for BGA, µBGA, QFP and CSP

by
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Abstract

"Circuit boards ride finer lines, but they appear to be stumbling over bigger holes" reads the introductory title to a July 22, 1996, article in Electronic Engineering Times[1]. This statement clearly presents the need for 'Via in Pad' blind vias that interconnect multiple layers in circuit board packages. Multi-depth interconnect technology that effectively will produce small blind vias within surface mount pads where they belong, is described in this paper. Laser drilled blind vias can be used to improve the interconnection and rework of Ball Grid Arrays (BGA), Micro Ball Grid Arrays(µBGA), fine pitch Quad Flat Packages (QFP) and is currently being reduced to practice for Chip Scale Packaging (CSP). This paper will discuss the design and fabrication of these laser drilled blind vias along with their limitations.

Introduction

Blind via technology has been around for a long time. Early adopters were military applications in the late 60's and early 70's where weight and size restrictions demanded advanced interconnect strategies. These early multilayer circuit boards were extremely expensive and used mechanical drilling techniques to create blind and buried via technology. In some cases through vias were carefully drilled through buried vias to create advanced and reliable interconnections.

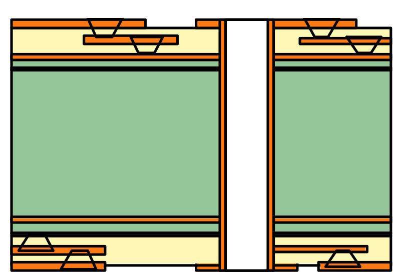
Blind and buried vias have seen limited use in conventional circuit board fabrication for nearly three decades even though the technology has been available. There are two reasons for the slow production development of blind and buried vias into main stream circuit board fabrication:

1) Cost: drilled blind vias could double fabrication costs
2) Density: component density has not demanded advanced via technology

As surface mount technology became main stream in the early 80's, component density still did not demand improvements in z-axis interconnect technology. Today, circuit layer counts are being driven higher and higher because drilled through vias have become so abundant. In fact, it has been reported that circuit board drilling is the single most expensive process step in board fabrication[2]. The Z-axis interconnect demand has created via starvation[3], where 'real estate' is not available to place through vias. This via starvation hinders both component density and circuit layer increases. *ENTER* the opportunity for blind vias, more specifically Via-in-Pad technology.

The Blind Via "Shoot-out"

Several blind via (and buried via) technologies are finding acceptance. All will find a niche in the very large market opportunity, but it is not clear which one or two will emerge as the leader. At the moment, it appears two *sequential build up* blind via technologies are leading the pack: Photo Via and Plasma Etch. Both technologies use special dielectric materials which have to be accepted by the OEM's. In order to make multi-depth interconnections with either Photo Via or Plasma Etch, sequential layer processing is necessary.



Sequential Build Up Blind Via Technology

A third blind via technology uses a laser beam to either ablate (break up the dielectric material bonds) or vaporize (boil off the dielectric material as a vapor). Several laser systems are attempting to process FR4 with limited success as far as maintaining clean, char-free vias and delivering reasonable drilling speeds. The FR4 laser processing challenge is actually in defiance of physics, where a beam of laser light energy is used to remove materials that greatly differ in vaporization states. More plainly put, vaporization or ablation of a glass-free polymer, typically epoxy or polyimide, takes only a fraction of the energy that is necessary to vaporize glass fibers or copper. Both the CO_2 and Nd:YAG laser systems currently on the market for processing FR4 have done remarkably well with the tough task of handling the beam focus, in process beam energy changes and motion movement. It is however, highly unlikely cost-effective laser systems can be marketed that will process over 100 vias per second.

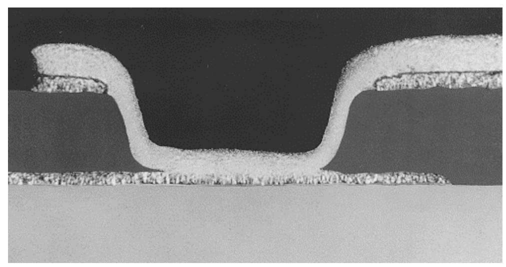
FR4 is a dielectric material nearing the end of it's life cycle as high performance circuit demands enter main stream. FR4 is best laser processed with a Nd:YAG laser system over a CO_2 laser system, since the Nd:YAG laser wave length is absorbed by the glass fiber and copper better than the dielectric polymer[4]. However, the opposite is true of the CO_2 laser wave length, as copper and glass fiber can act as a natural reflector of the low energy beam allowing single pulsing per via and much faster processing.

This paper will briefly describe a specific laser technology that allows a laser system to drill-on-the-fly over a panel with etched windows or relief openings in the outer layer copper foil[5]; and make multi-depth interconnections.

The History of LaserVia™ Technology

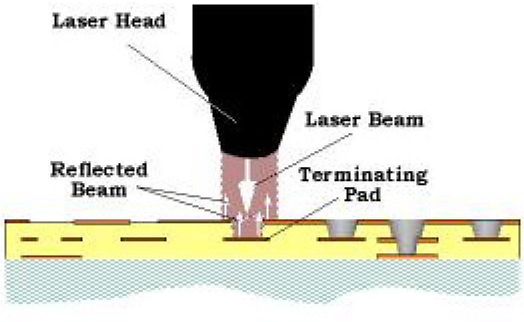
In 1980, before surface mount technology found it's way from ceramic hybrid manufacturing into the circuit board industry, a blind via technology was developed and patented[6] whereby a dielectric material was screened onto the surface of an all copper circuit board. The screen had pads that kept the polymer dielectric from covering specific area on the outer surface and after either additive or semi-additive plating these areas void of polymer dielectric became blind vias. Two years later the screened blind via size was reduced by more than one half.

In 1983 and 1984 an opportunity was made available to spin off the blind via technology. Moving this screened technology into a merchant conventional multilayer circuit board fabricator was not as easy as originally thought. After careful evaluation and experimenting, a laser system was used for making blind via interconnections using an epoxy glass-free substrate[7]. The panel was fabricated with a glass-free epoxy cover coat manufactured by Fortin Laminates (now absorbed into AlliedSignal Laminate Systems) using copper foil.



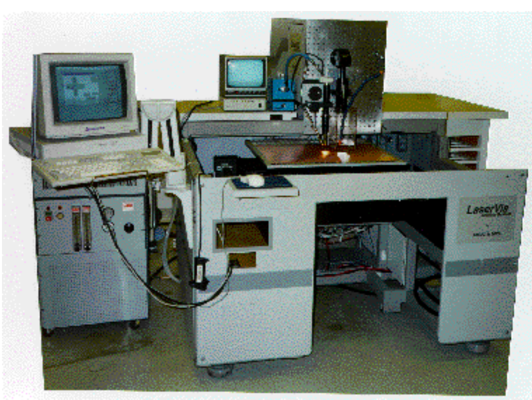
Laser Drilled Blind Via ~ 1985

This all epoxy resin material eventually evolved into AlliedSignal's RCC™. In 1986/1987 a laser system was built by Electro Scientific Industries to a custom design specification for drilling blind vias using coated foil. The system was capable of drilling at 200 vias per second on many designs. This laser system was basically too low in wattage to properly drill even very thin epoxy without multiple pluses, since a 50 watt RF controlled CO_2 laser was used from the medical industry. The table moved only in the Y axis and the beam was positioned and moved in the X axis over the table with the use of tightly controlled mirrors.



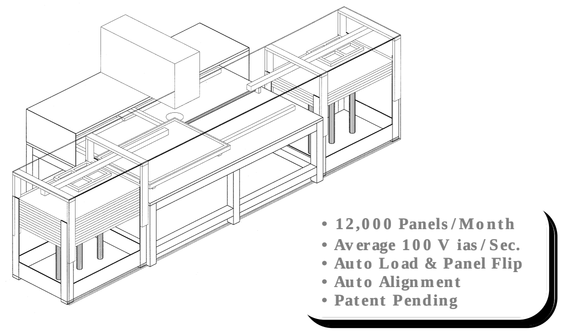
Drill-On-the-Fly LaserVia™ Technology

Sandia National Laboratories was funded and instructed to introduce a circuit board laser drilling technology. It was difficult to find a laser system integrator that would take the initiative to build a system incorporating the elements of LaserVia™ Technology. As part of the Sandia project a laboratory system was put together using a Coherent Diamond™ 160 Watt RF controlled CO_2 laser to drill some test panels for Sandia[8]. The test design incorporated a series of daisy chain connected QFP and BGA plus a long daisy chain grid of over 5,000 six and eight mil laser drilled blind vias per side. Zycon Corporation collaborated by processing the boards. The test incorporated over 5 million LaserVias and resulted in the purchase by Sandia National Laboratories of a laser drilling system and a LaserVia™ Technology R&D License. Cut backs in federal funding has hindered the progress of the project.



Current LaserVia™ Drilling System ~ 1995

In 1995 a system was built using an older motion system and other components that can drill at 25 vias per second. The dated motion system limits the table movement to an average of 3 inches per second and therefore the via per second output. A production model has been engineered and designed with a motion system that will move at an average of 20 inches per second and is expect to drill at 100 to 300 vias per second depending on the circuit design.



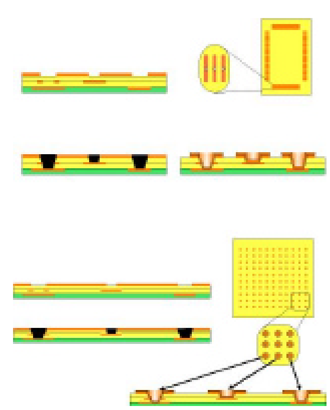
New LaserVia™ Drilling System

Multi-depth Laser Drilling for BGA, µBGA & QFP

This author believes the keys to introducing a new Z-axis interconnect process that will improve and complement the current impressive mechanical small hole drilling processes are:

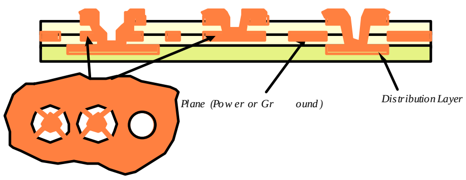
- Multi-depth blind via interconnection,
- Single step process,
- Compatible to multilayer processes,
- Cost-effective, and
- Reliable processing.

Current high speed designs typically call for a plane (either power or ground) to be positioned just under the outer layer. The following design rules depict such a layout for laser drilling to multiple depths.

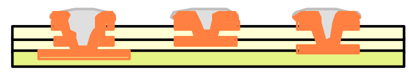


The limitation of these multi-depth laser drilled blind vias is the ability of the fabricator to plate into the blind vias. The finished board may be all copper or hot air leveled as shown below:

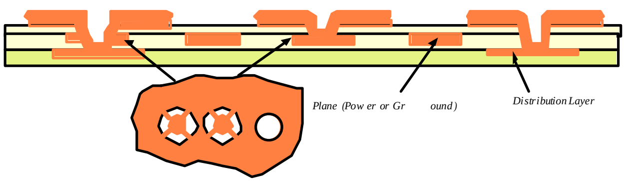
QFP Pad Stack ~ Layer 2 Plane



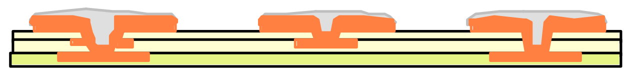
QFP Pad Stack Hot Air Level



BGA Pad Stack ~ Layer 2 Plane



BGA Pad Stack Hot Air Level



Laser Drilled ~ All Copper

Laser Drilled ~ Hot Air Leveled

Current Available LaserVia™ Dielectric Materials

	Epoxy/Thermount® (Epoxy/Aramid) *	RCC™ (Epoxy Foil)	*New* FoldMax™ (BT/Non-Woven Organic)	*New* LCP-TL-100 (Liquid Crystal)	*For Comparison* FR4 (FR402)
Vendor(s)	NelTec	AlliedSignal	Mitsubishi International	Superex	AlliedSignal
Dielectric Constant @ 1 MHz	3.9	3.4	3.3	2.9	4.3
Dissipation Factor @ 1 MHz	0.024	0.026	0.015	0.009	0.020
Volume Resistivity (ohm-cm)	7×10^{13}	7×10^{13}	----	10^{16}	3×10^{7}
Surface Resistivity (ohm-cm)	8×10^{14}	9×10^{14}	1×10^{13}	1×10^{13}	1×10^{7}
Electric Strength (V/mil)	1200	1760	----	5500	1100
Water Absorption	0.5%	0.9%	0.2%	<0.02%	0.1%
Glass Transition Temperature(T_g)	145 °C	160 °C	180 °C	----	140 °C
CTE (25 °C to 150 °C) X Axis	10ppm/ °C	57ppm/ °C	8ppm/ °C	7ppm/ °C	14ppm/ °C
CTE (25 °C to 150 °C) Y Axis	10ppm/ °C	57ppm/ °C	18ppm/ °C	7ppm/ °C	14ppm/ °C
CTE (25 °C to 150 °C) Z Axis	115ppm/ °C	57ppm/ °C	65ppm/ °C	125ppm/ °C	85ppm/ °C
U.L. Flammability	94V-0	V-0	94V-0	94V-0(0.031)	94V-0(0.031)
Peel Strength (1oz. Cu, 25 °C)	6 lb/in	6 lb/in	9 lb/in	6 lb/in	10 lb/in
Core thickness (in mils)	1.8 and up	1.8	2.0 and up	1.2,2,3,3.5, & 4	1.5 and up
Prepreg thickness (in mils)	1.8 & 3.0 & 4.0	Not Available	2.0 & 3.1	Not Available	1.5 to 6.9
***Estimated* costs compared to FR4**	3x	1.2x	2x	0.8x - 1.2x	1 **

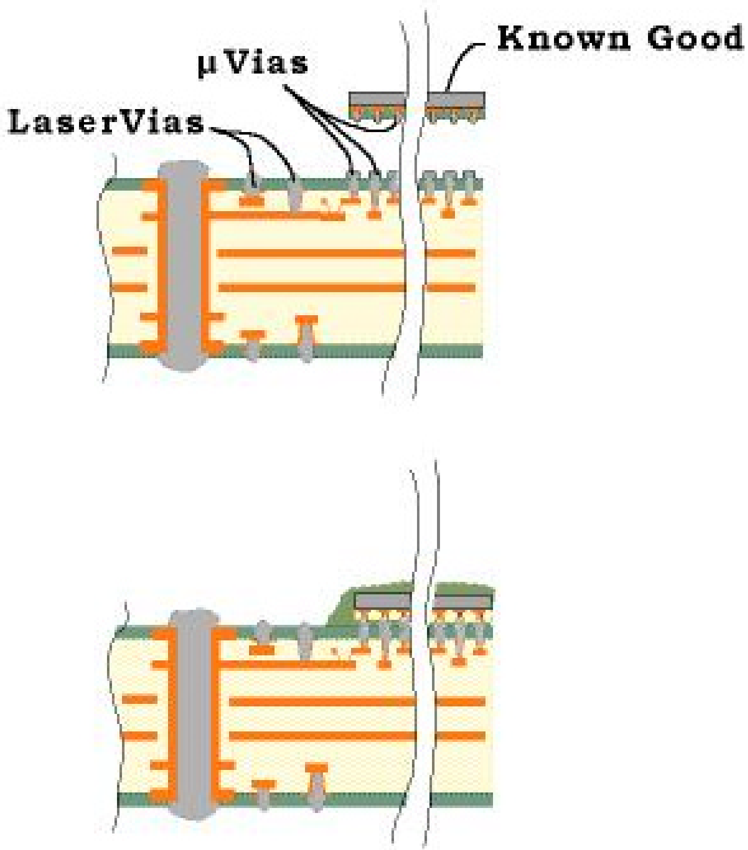
Thermount® is a registered trademark of DuPont Fibers
*Epoxy/Thermount® is produced by NelTec/PolyClad/Arlon as both Thin Core and Prepreg.
RCC™ is a trademark of AlliedSignal Laminate Systems (Coated Foil)
FoldMax™ is a trademark of Mitsubishi Gas Corporation (Thin Core and Prepreg)
**FR4 is not a useable LaserVia™ Dielectric Material (priced at $7.84/18"x24" sheet 0.002")

Table 1

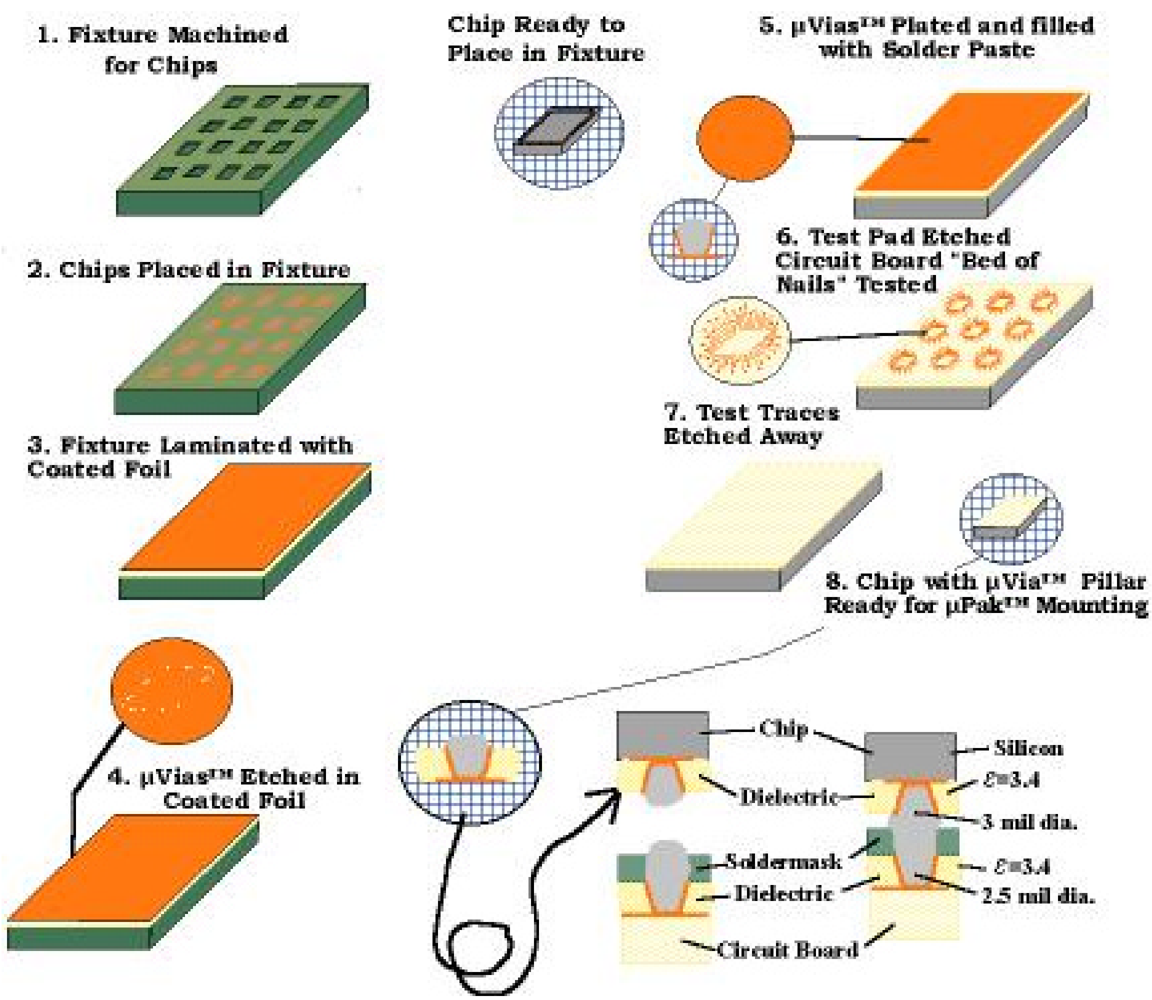
New materials shown above in Table 1 have been introduced recently that promote laser drilling. Many of the characteristics of these new materials are an improvement over conventional FR4.

Chip Scale Packaging

A small amount of testing has been completed that allows this author to believe a simple interconnect scheme whereby a laser drilled blind via placed on a Known Good Dye (KGD) could be bonded as a flip chip over a similar footprint configuration as shown below:



The process is generally defined as pictured below:



Chip Scale Packaging Interconnect Scheme

Conclusion

Laser drilling of blind vias to multiple depths can produce interconnect packages that fit into today's conventional circuit board fabrication. The ability to produce multi-depth blind vias within surface mount component pads at the rate of 100 to 300 vias per second can be accomplished by taking the path of least resistance. One such path that flows with the laws of physics is to use an RF controlled CO_2 laser system set to drill-on-the-fly with a single pulse over etched 'windows' as a copper mask.

Biography

Larry Burgess has over 30 years experience in the interconnect packaging disciplines. He received a Bachelor's Degree in Chemistry from Lewis and Clark College. Mr. Burgess holds several patents pertaining to laser drilling of printed circuit boards and laser systems. He managed the circuit board development laboratories at Tektronix prior to founding a start up called Interconnect Technology Inc. Interconnect Technology also introduced a laser drilled blind via technology as one of the first production facilities to place blind vias within surface mount pads. Currently Mr. Burgess is opening the first of several, sequence subcontract, circuit board laser drilling centers in the United States. Mr. Burgess has given multiple papers at Nepcon, IEPS, IPC and ISHM and written and contributed to multiple published articles. He is a member of IPC, IEPS, ISHM, SAMPE, SMTA and IEEE.

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